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SMALL-SCALE ERUPTIVE FILAMENTS ON THE QUIET SUN

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Abstract

We conducted a study of a little known class of eruptive events on the quiet sun. 61 small-scale eruptive filamentary structures were identified in a systematic survey of 32 days of Hα time-lapse films of the quiet sun acquired at Big Bear Solar Observatory. When fully developed, these structures have an average length of 15 arc seconds before eruption. They appear to be the small-scale analog of large-scale eruptive filaments observed against the disk. At the observed rate of 1.9 small-scale eruptive features per field of view per average 7.0 hour day, we estimate the rate of occurrence of these events on the sun to be greater than 600 per 24 hour day. The average duration of the eruptive phase was 26 minutes while the average lifetime from formation through eruption was 70 minutes. A majority of the small-scale filamentary structures were spatially related to cancelling magnetic features in line-of-sight photospheric magnetograms. Similar to large-scale filaments, the small-scale filamentary structures sometimes divided opposite polarity cancelling fragments but often had one or both ends terminating at a cancellation site. Their high numbers appear to reflect the much greater number and mixture of small-scale than large-scale aggregates of opposite polarity magnetic flux on the quiet sun. From their characteristics, evolution and relationship to photospheric magnetic flux, we conclude that the structures described in this study are small-scale eruptive filaments and are a subset of all filaments.

1. INTRODUCTION

While surveying Hα time lapse films of the quiet sun recorded at the Big Bear Solar Observatory, we have occasionally noted a small fibril or filament-like structure which would expand into an arch, break open at its top, and disappear. These phenomena appear similar to the eruptive phase of large-scale filaments photographed against the solar disk or large-scale prominences photographed at the limb. An example is illustrated in Figure 1. The event is the darkest feature in the middle of the frames from 19 56 20 until 20 08 44. It already is recognizable as a small loop in the first frame at 19 48 33. The loop breaks open at its top between 20 01 30 and 20 04 44. After that time, the ends of the loop slowly disappear; the event is over by the last from at 20 18 31. In most small-scale eruptive events, the loop is not viewed as much from the side as in Figure 1. More typically, the events exhibit a small degree of lateral displacement before disappearing. Observations in the blue wing of Hα confirm the lateral motion to be the plane of sky component of outward erupting mass.

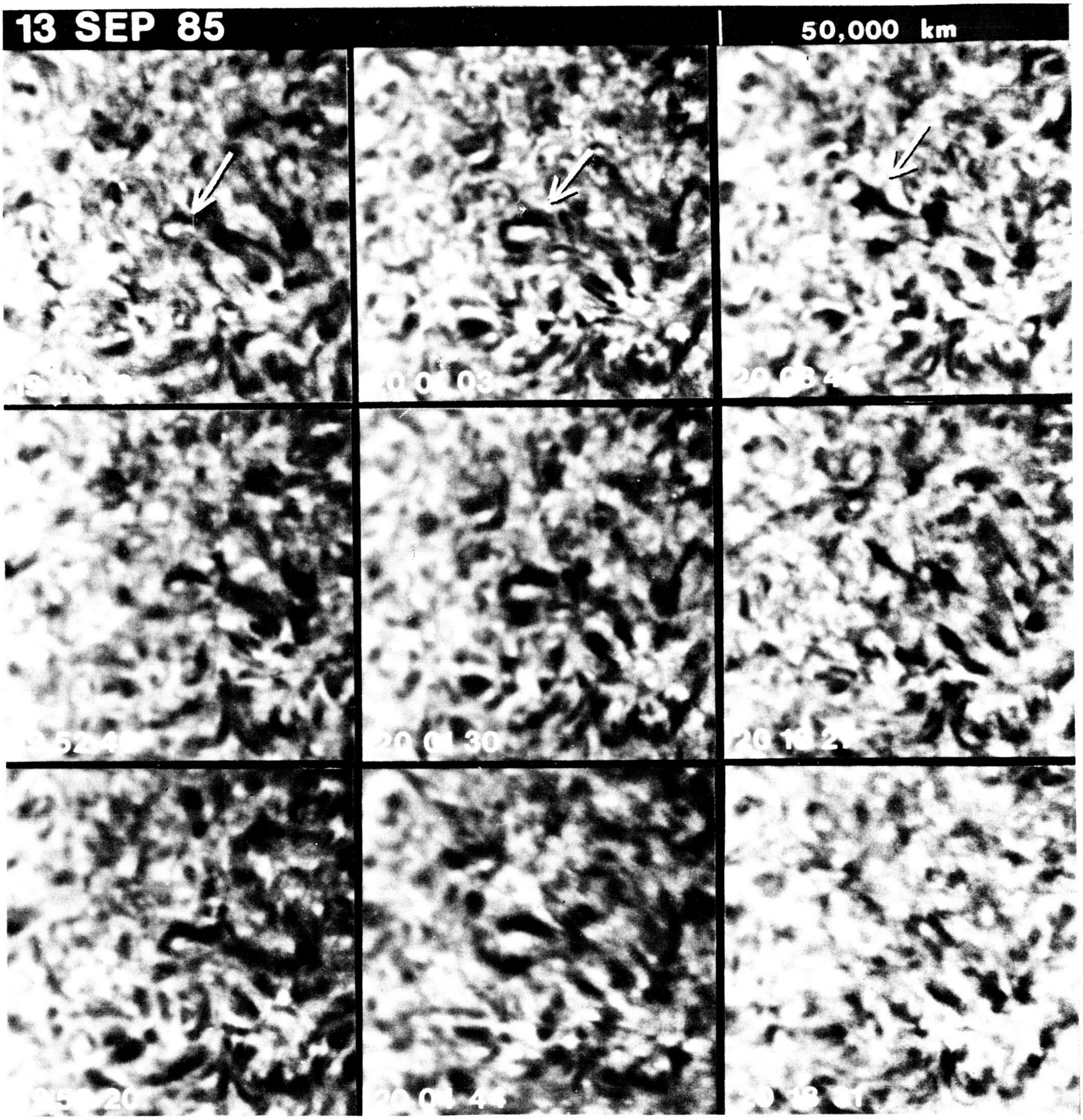

Fig. 1. Arrows on the upper image of each consecutive column of Hα images point to the development and eruption of a small filamentary loop. In addition to exhibiting a pattern of motion common to many large-scale erupting prominences, the event also increases in absorption as it expands similar to pre-eruptive phase of large-scale filaments seen in projection against the solar disk. The loop breaks open at its top (between 20 01 30 and 20 04 44) where the Doppler shift is typically greatest. By 20 18 31, the legs of the loop have also disappeared.

After about 10 of these small-scale eruptive events had been noted, we decided to make a systematic survey of a selection of recent time-lapse films to study the properties of the small-scale eruptive events and to estimate their number on the quiet sun during solar minimum. In this paper we present the initial results of this analytical survey.

2. THE OBSERVATIONS

We initially chose to limit our systematic survey to Hα films to a recent interval since 29 August 1985 when many quiet sun observations were made. We further limited the survey to conditions when: (1) concurrent long-integration videomagnetograms with increased sensitivity were recorded with a CCD television camera. (2) at least 1 hour of observations were acquired on a single area of the quiet sun in the center of the Hα line, (3) the rate of filtergram acquisition was 2 or more frames per minute, and (4) the image quality for the majority of the day was visually estimated to be 2 or higher on a scale of 4. Between 29 August and 1 November 1985, observations made on 30 days met these criteria. We added to the survey, 2 and 3 August 1985, days which met the latter three criteria above and coincided with the Spacelab II flight.

The quiet sun observations on most of the days surveyed were biased towards observations near the center of the solar disk. It was a purposeful bias to obtain maximum signal in the videomagnetograms of the line-of-sight component of magnetic flux. The observations reported here were all acquired before this study was conceived. The field of view during the interval of this study was approximately 300 $\times$ 240 arc seconds.

3. RESULTS

3.1 Number of Events

During our survey, 63 conspicuous eruptive events were found in the 32 days of observations selected for this study. 61 of the 63 erupting filaments were considered to be small-scale; most of these are events that would not be easily recognized in full disk Hα images. Usually the features initially resembled either filaments or fibrils in which the length of the feature is much longer than its width although occasionally an event, such as the one in figure 1, will have a loop shape when it first appears. Because our first objective is to clearly and accurately illustrate and describe these events as a class, we have restricted our analyses to only those events which revealed clear evidence of lateral displacement and expansion in'o an arch before its disappearance. This restriction eliminates any possible confusion with spicules, small surges and other events which show only mass motion along the length of the feature. However, this restriction also means that events which erupted primarily in our line-of-sight are excluded in this study. Hence, the numbers we report are a lower limit to the actual number of small-scale eruptive events that occur on the sun. Our counts of eruptive events could be low by a factor of 2 or more.

The average number of small-scale eruptive filamentary structures was 1.9 events per 7.0 hour average observing day per average field of view of 300 X 240 arc seconds. Except for the polar regions, which were not sampled above about 65 degrees, this number can be used to roughly estimate the number of events occurring per day of the sun. Even with the exclusion of the polar regions, we find that more than 600 small-scale eruptive events occur on the sun per 24 hour day.

3.2 Size of the Events

For each eruptive event we measured the linear distance in the plane of the sky between the end points of each feature. The measurement was made at the beginning of the lateral displacement and usually represents the maximum dimension of the feature at the top of the chromosphere. No correction was made for foreshortening. The distance between the ends of each feature ranged between 5 and 54 arc seconds with the average at 15 arc seconds.

3.3 Duration of the Events

30 of the 61 small-scale eruptive filamentary structures were observed from their formation through their complete disappearance. The range of lifetimes of these events was 15 and 201 minutes. The average lifetime was 70 minutes.

The eruptive phase, for the purposes of this study, is defined as beginning with our visual detection of the start of the lateral displacement and outward expansion of the small filaments and continuing until the structure completely disappeared. In a few cases, the lateral motion and expansion into a loop was already taking place while the filament was still developing. More often, however, the structure exhibited an earlier active phase that was longer than the eruptive phase. For 50 of the 61 events, the shortest observed eruptive phase was 6 minutes and the longest was 77 minutes with the average eruptive phase lasting 26 minutes.

3.4 Evolution of the Phenomenon

The small-scale filamentary structures spontaneously appear against the background of chromospheric fibrils without apparent association with pre-existing or underlying structures. Most are a single curvilinear structure similar in size to the surrounding chromospheric fibils. Within minutes to tens of minutes after formation, they usually become distinguishable from other chromospheric structures by their motion, changes in shape, and increasing degree of absorption. They gradually evolve from this active phase to the eruptive phase. Like large filaments, the eruptive phase seems to be an irreversible process. The expansion into an arch or loop continues until the disappearance of the whole phenomenon as illustrated in Figures 1.

3.5 Association with Flares

75 percent of the small-scale eruptive structures were associated with very small flares. The flares occur during the eruptive phase similar to flares associated with large-scale erupting filaments. The event in Figure 1 is not flare-associated. In Figure 2, the associated small flare is seen in the last Hα image at 2205 05 near the base of the right leg of the event.

3.6 Counterparts at Other Wavelengths

K. Harvey (1986) has identified dark features that correspond to the small-scale eruptive filaments in 10,830 Å spectroheliograms. In most cases, the 10,830 Å absorption is seen during the active and eruptive phases but does not necessarily correspond to the entire lifetime an event. We would expect these small-scale eruptive events to be visible in any other chromospheric line that reveals filaments.

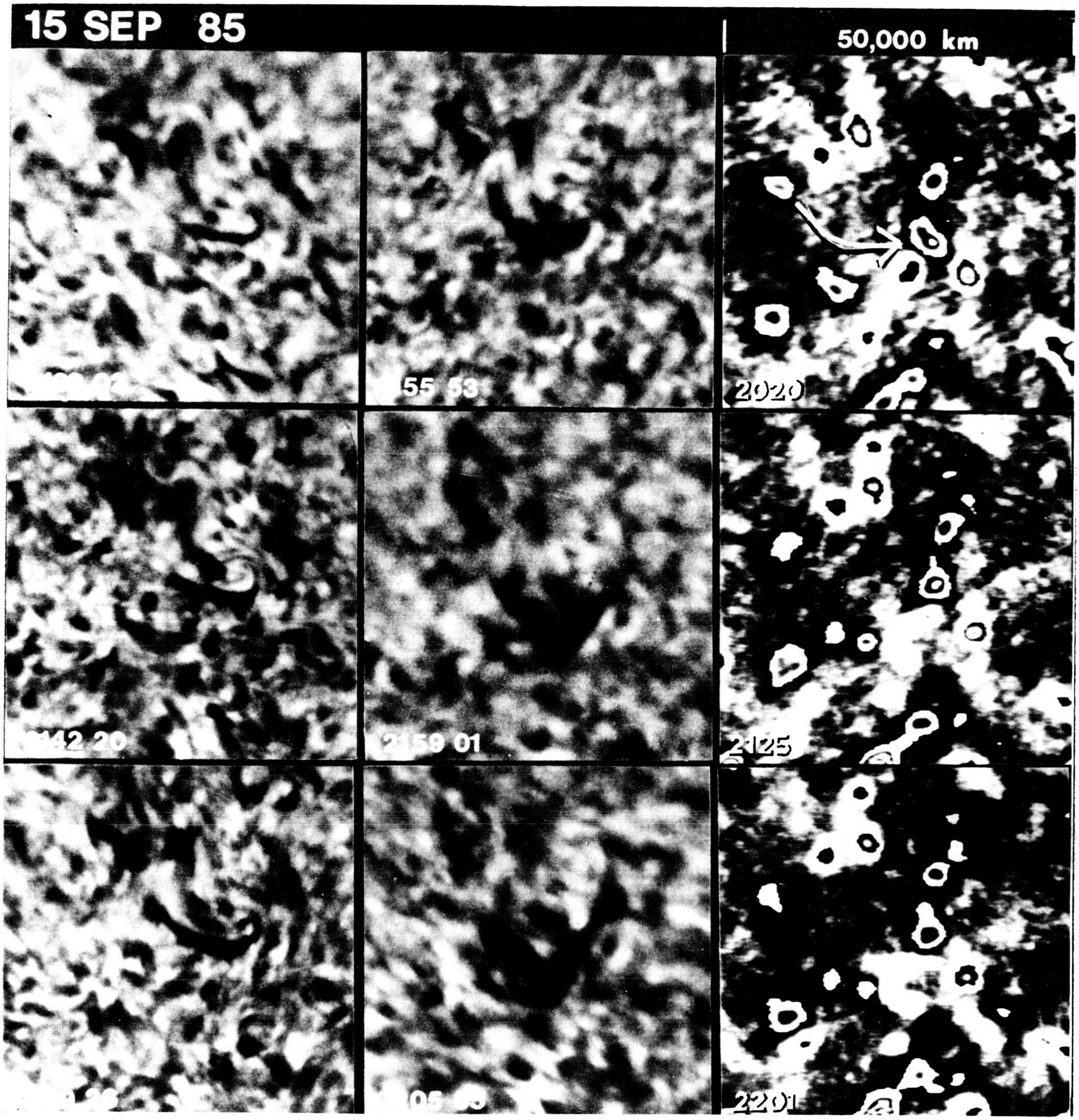

Fig. 2. The position of this small-scale eruptive filament relative to the line-of-sight component of the surrounding photospheric magnetic flux is marked the curved arrow in the top image of the column of magnetograms on the right. The filament lies between separated fragments of opposite polarity magnetic flux while the right end of the filament terminates at the junction between cancelling fragments of adjacent magnetic flux of opposite polarity. The decrease in the magnetic flux is seen from the reduction in area and contours. Negative fragments of flux are black and positive are white except within the contours where the polarity is the same as around the periphery.

We suggest the possibility that 'jets' observed in the ultraviolet (Brueckner 1984) are a coronal manifestations of the small-scale eruptive filaments. Both kinds of events are similar in scale, eruptive in nature, often identifiable as having a loop shape, and have high rates of occurrence. The 'jets' are identified in spectra which emphasizes their line-of-sight speeds whereas our sample of filtergrams of the small-scale eruptives emphasizes their motion in the plane of the sky. This hypothesized association could be tested by acquiring Hα or 10,830 Å spectra concurrently with filtergrams of an adequate statistical sample of the small-scale eruptives at the same wavelengths or more directly by acquiring simultaneous observations of UV spectra and Hα filtergrams, preferably at various wavelengths around line center.

Other possible associations between the small-scale eruptives, their associated flares, and various other small-scale coronal features such as coronal 'bright points', ' bright point' flares, 'dark points' in 10,830 Å spectroheliograms and compact radio sources are discussed by Webb (1986).

3.7 Association with Photospheric Magnetic Flux

We have begun a study of the correspondence of the positions of the small-scale filaments to photspheric magnetic flux seen in videomagnetograms of the line-of-sight component. Of the first 20 events examined for which there were corresponding magnetograms, 15 appeared to be spatially associated with cancelling magnetic features and for the other 5 no specific pattern has yet been recognized. Those associated with cancelling magnetic features are comprised of two variations. In 6 examples, the filament was coincident with the division between opposite polarites of the cancelling features and in 9 examples, one or both ends of the small filament terminated near the division between opposite polarities of the cancelling features.

An example of one of the small-scale eruptive events with one end terminating at cancelling magnetic fragments is shown in Figure 2. The magnetograms are the third column of images following the two columns of Hα images to the left. An arrow on the first magnetogram denotes the path of the small filament; the head of the arrow points to the two adjacent opposite polarity cancelling fragments. Negative flux is black and positive flux is white for all areas outside of the contours. The area within the contours always has the same polarity as around the periphery of the contours. The contours enclose areas of higher magnetic flux in which the number of concentric contours, alternating from black to white or white to black, represents the number of time that the saturation level has been exceeded. The cancelling flux is recognized from the decrease in area and contours at the right of the arrow in contrast to other fragments of magnetic flux of similar size. The localized cancellation of magnetic flux begins before the initial appearance of the small filament.

4. DISCUSSION

The small-scale features described in this paper exhibit properties similar to large-scale filaments and prominences. Their formation, evolution, and eruptive character and association with flares during eruption are all similar to large-scale filaments. Their frequent relationship with cancelling fragments of magnetic flux is an association that has also just begun to be recognized as commonplace for large-scale filaments (Martin, 1986, these proceedings). The most obvious difference between these small-scale eruptive events and large-scale eruptive filaments is their much higher rate of occurrence. At present, we do not consider this to represent a fundamental physical difference. In their pre-eruptive state, both the small-scale structures and large-scale filaments are associated with polarity inversion zones in magnetograms of only the line-of-sight component of magnetic flux. Because of the greater number and mixture of opposite polarity, small-scale magnetic features on the sun (Giovanelli 1982), there is also a correspondingly greater abundance of small-scale polarity inversion zones where small filaments have the opportunity to develop. We conclude that the structures described in this study are small-scale eruptive filaments. We recognize the small-scale eruptive filaments to be a subset of all filaments.

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